ADMINISTRATIVE INFORMATION

1. **Project Name:** Structurally Integrated Coatings for Wear and Corrosion

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5. **Date Project Initiated:** January 1, 2004

6. **Expected Completion Date:** December 31, 2006

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The proposed work effort will develop improved, cost effective surfacing materials and processes for wear and corrosion resistance in both sliding and abrasive wear applications. Materials with wear and corrosion performance improvements that are 4 to 8 times greater than heat treated steels are to be developed. Affordability will be assessed against other competing hard surfacing or coating techniques, balanced with overall materials performance. Where practical, state-of-the-art design and simulation capabilities will be incorporated to guide materials and process refinement.

8. **Technical Barrier(s) Being Addressed:** Materials degradation by simultaneous wear and corrosion is responsible for failure and life reduction of many components such as track undercarriage, ground engaging tools, piston rings and liners, engine valves, pumps, or other mobile systems. Because of the complexity of high wear resistant and corrosion resistant surface modified structures, an empirical approach is not only extremely time consuming and labor extensive, but also limited in the number of potential parameters that can be evaluated. The primary hurdle to the development of coatings to meet the goal of 4-8 times life improvement over current carburized steels is the balancing of the following: choice of substrates, processing contraints, and alloy systems to produce high hardness, corrosion resistant coatings with high toughness. The proposed economic analysis, materials development, and processing design efforts will combine to address this issue. Coating cracking is perhaps the most difficult technical obstacle to overcome with the usage of extremely

hard materials. To overcome this hurdle, efforts will be made to engineer crack free coatings and FGM designs that provide corrosion resistant and compliant base layer(s). Residual stress profiles of coatings will yield additional insights for input into materials and process design. Finally, it is recognized that necessary thermodynamics or kinetic data will be lacking with some of the materials systems utilized for surfacing and this will impact on the accuracy that can be achieved with the materials and processing simulation.

9. **Project Pathway:** Four deposition processes will be investigated for applying the surfacing materials: arc lamp fusing of thermal spray coatings, laser-aided thermal spraying, hybrid laser-arc cladding, and plasma transferred arc (PTA). Material design and process simulation capabilities to guide materials and process refinement will be used to aid the development of the cost effective solutions. Systematic process simulation will be performed to augment experiments via numerical modeling based on a combination of transport phenomena, material science, and engineering mechanics. This approach will be effective in optimizing processing parameters to achieve the desired deposited material properties and performance. Potential hard facing materials and deposition processes will be categorized as individual concepts and evaluated for their potential to meet the requirements of the application. For concepts that meet the initial application criteria, more detailed modeling will be developed. These concepts will then be evaluated and a design analysis completed. The most promising candidates will be prototyped and evaluated experimentally. Design of experiments techniques will be used to evaluate each concept to determine the robustness of the design and validate the design assumptions and models. This methodology will streamline the development activity and enable a comprehensive solution to be accomplished.

10. **Critical Technical Metrics:**

- Develop two or more materials systems that provide a 4-8 times wear and corrosion resistance increase over current carburized steels.
- Develop two economically attractive processes for depositing coatings
- Determine intrinsic and extrinsic properties required for modeling of promising materials systems/coatings
- Modify existing and develop new testing methods as needed for quantitatively ranking the toughness of high performance, metallurgically-bonded coatings
- Model the microstructural evolution of high performance coatings during processing
- Analyze the feasibility of each coating process in terms of both economic viability and likelihood of industrialization resulting in “go” or “no go” decisions

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** Not applicable, project initiated in FY04.

12. Future Plans:

1. Economic and industrial feasibility analysis of each coating process and selection of candidate processes and materials. Completion date end of 4th quarter, 2004.
2. Estimation of feedstock materials costs and any associated processing required prior to coating deposition. Completion date end of 4th quarter, 2004
3. Initial coating production with each coating process, using up to four material systems per process. Completion date end of 4th quarter, 2004
4. Metallurgical analyses of coatings. Completion date end of 4th quarter, 2004
5. Determination of material and coating properties required for microstructural modeling. Completion date end of 1st quarter, 2006

6. Coating microstructural evolution modeling. Completion date end of 1st quarter, 2006
7. Mechanical/toughness screening of promising coating systems. Completion date end of 2nd quarter, 2006
8. Laboratory wear and corrosion screening of coatings (ASTM G65, Caterpillar's tribo-corrosion test, etc.). Completion date end of 2nd quarter, 2006
9. Produce coated components for lab bench testing. Completion date end of 2nd quarter, 2006

13. **Project Changes:** None.

14. **Commercialization Potential, Plans, and Activities:** The technologies to be developed in this work effort are applicable to many industries. The integration of laser technology with thermal spray processes and arc welding would not be difficult for others to acquire and the material systems to be developed have shown promise to be cost effective for industry. Both the laser assisted thermal spray and hybrid laser-arc processes are patented by the Fraunhofer Institute of Germany and are available for licensing. Commercialization of arc lamp fusing will require purchase of an arc lamp by Caterpillar and is part of the program cost share if the process is selected as a prime path. This will allow for commercialization of the developed technologies by Caterpillar. Materials developed as part of this program will be made available through the program participants for use by others. It is the intent of Caterpillar to protect via patents the processes and materials to be developed. The processes and materials would then be available for licensing to third parties that are not in direct competition with Caterpillar. This will allow for implementation of the technology by a wide range of industries.

15. **Patents, Publications, Presentations: None to date.**